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Review on Building Energy Management Systems by Retrofitting Existing Buildings with Green Technology

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Abstract: With global energy consumption on the rise, it is imperative to develop energy-saving measures. Since old buildings consume a significant amount of energy, it is important to assess them as potential upgrade opportunity. Retrofitting in the context of buildings is the addition of new hardware or software components to a facility to improve its performance. Retrofitting an old building is one strategy to minimize reliance on the construction of new buildings. There are several old buildings that can be retrofitted with green technologies. Hence, the purpose of this study is to give information on the review and investigation of building energy management systems by retrofitting existing buildings with green technology. Site visits and walk-through inspections are conducted after selecting the C16 FKMP building as the study's objective. The building's energy consumption has been calculated, and data has been gathered. The data was then used to estimate and propose energy conservation measures such as lighting system retrofitting and solar photovoltaic systems. Retrofit should be promoted throughout the building and conservation industries due to its numerous advantages. It is one of the most eco-friendly and cost-effective strategies for optimising energy performance and extending the lifespan of existing buildings.

Keywords: Retrofit Green Technology, Energy Consumption, Energy-Saving Measures

1. Introduction

In the next 20 years, the amount of energy buildings use is expected to rise by more than 40%. If you live in a building, electricity is still the most common source of energy, and demand is rising. Initiatives to make buildings more energy efficient are needed to lessen the effects of an increase in consumption. People who live in non-residential buildings use more energy because of things like space

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heating as well as other things such as electronic devices, air conditioning, and etc. Building energy management system enables building managers and owners to improve the energy efficiency of both new and old structures [1]. Energy consumption by buildings accounts for 30–45 percent of global energy consumption, with the building subsystems, which include cooling and heating systems, as well as fire and security systems, as well as water distribution and lighting systems, and other similarly integrated subsystems, accounting for most of the energy consumption[2]

The objective of this study is to review and explore the existing green technology that can be retrofitted to existing buildings by reviewing past studies that has been conducted. Then, the energy consumption data for C16 FKMP building will be collected and be used for the retrofitting study for existing buildings such as C16. Then finally, propose energy conservation measures based on the data collected from the case study of C16 FKMP building.

As a result, building owner would benefit greatly from the retrofitting green technology because it allows the buildings to use less energy and dependency on fossil fuels. This would result in significant savings in the long run.

2. Materials and Methodology

The materials and methods section, otherwise known as methodology. In this part, research project must have a defined methodology that allows for a clear understanding to aid in achieving the study's goal. The methodological guide may ensure that the study is carried out correctly and methodically to get the intended outcomes. It is an excellent means of tracking the progress of this inquiry and ensuring that it stays focused on the topic of the study.

2.1 Data Collection

The data collection procedure for the selected building is divided into two sections: information about the physical and operational characteristics of the selected building, and field measurements of environmental parameters inside the buildings. The purpose of FKMP C16 building, and utility data is to determine the characteristics of the building's energy systems and the energy consumption patterns. The data obtained contain information about the building's attributes. The consumption of electrical energy is determined by compiling utility bills over a period of several years. The analysis of previous utility bills enables the researcher to ascertain any seasonal and weather influences on the building's energy consumption. The information about the physical and operational characteristics of the selected building is divided into two sections. These are the main points to note about the data collection procedure that was used in this study:

- The files and data were used to collect the building's as-built drawings, architectural details, specification reports, exterior configurations, and materials.
- The details of the layout and configurations of the buildings and the details of the buildings and their parameters were investigated using self-reported field data.
- Selected rooms in the building were subjected to an energy consumption analysis.

2.2 Literature Review

Literature review is important to obtain useful information about the related field of study from past research. A comprehensive analysis and debate findings in a specific field can be explained in literature review. It is useful to identify discrepancies in literature according to identified topics. The main purpose of conducting literature review is to know the background of study. When sieving through different sources, a lot of information related to scope of study can be acquired. In this study, one of the main of objectives is to review and propose energy conservation measures.Sources for literature review conducted in this study are from articles, journals, books, web pages, and reports. The building energy management system and retrofitting green technology are based on existing and current technology. The most used databases for literature review would be ScienceDirect, Scopus, ResearchGate and Springer Link. The journals are searched based on keywords which will be identified to widen the search results.

2.3 Data analysis for C16 FKMP Building Case Study

This step involves the development of a base-case model that accurately portrays the building's current energy consumption and operating conditions. This model is used as a reference to estimate the energy savings due to suitably selected energy conservation measures. The following components are taken into consideration:

i. Estimation of annual energy use in Building C16 FKMP

ii. Usage electrical equipment such as lightings, air conditioning, and other electrical equipment.

The formula for the calculations will be shown below:

$$\text{Power Consumption}: = \frac{\text{Input Power }(Watts) \times \text{Hours of operation per year} \times \text{total unit}}{1000} \qquad Eq. 1$$

$$\text{Number of Luminaires}, N = \frac{E \times A}{F \times UF \times MF} \qquad Eq. 2$$

$$\text{Illuminance}, E = \frac{F \times N \times MF \times UF}{A} \qquad Eq. 3$$

$$\text{Cooling Capacity}, C_T = (C_1 + C_2 + C_3 + C_4) \times 10\% \text{ increase} \qquad Eq. 4$$

$$(BEI) = \frac{\text{Estimated annual energy consumption }(kWh/yr)}{\text{Gross Floor Area }(m^2)} \qquad Eq. 5$$

$$\text{Estimated Energy Saving} = \text{Existing Consumption} - \text{Estimated Consumption} \qquad Eq. 6$$

$$\text{Payback Period} = \frac{\text{Estimated Cost Saving}}{\text{Retrofit Cost}} \qquad Eq. 7$$

Each numbered equation should be in its line and be separated from the surrounding text by the default line spacing. Eq. 1, as are all equations, should be referenced in the text.

3. Results and Discussion

The results and discussion section presents in details of the findings from comprehensive literature review and gathered data from the walk-through site inspection.

3.1 Review and explore the existing green technology by retrofitting existing buildings.

From the literature study, there are 4 types of green technology were identified and chosen for this study which comprises of solar energy, building automation systems, rainwater harvesting and the benefits of retrofitting existing buildings. All of them were found significantly useful in retrofitting existing buildings in many ways as shown in Table 1.

Table 1 Literature review of types of green technology and the contributions

Types of green technology	Contribution as green technology
Solar Panels	Building Integrated Photovoltaics (BIPV) uses less raw materials[3] Encourages power generation and regarded one of the best renewable energies.[4] Solar power generation is the cleanest option to produce electricity[5] Solar panels improve the buildings environmental value[6]
Building Automation System	Sensors to improve and reduce energy consumption at home.[7] Govern the operation of electrical equipment, reducing unnecessary energy wastage.[8] Managing energy usage via integrated automation system.[9] Lighting and shades are adjusted according to surrounding environment.[10] Building automation system reduces residential energy usage.[11]
Rainwater Harvesting	Rainwater harvesting allows for the conservation of water.[12] Designing umbrella-shaped water collector to prevent water loss.[13] Using solar energy to process harvested rainwater reduces the use of non-renewable energy.[14] Utilisation of harvested rainwater to reduce usage of clean water.[15] Using modern technology to collect rainwater in a cost-effective manner.[16]
Benefits of Retrofitting	Different types of retrofits can be implemented on older buildings.[17] Retrofit provides better thermal comfort.[18] Retrofit existing buildings is cheaper than constructing a new building.[19] By improving the building, the productivity rates increase significantly.[20]

Solar energy is considered as a green technology because of its practicality. It is said to be the most environmentally friendly source of generating power [5]. Solar energy may be generated by incorporating solar panels onto homes or structures that allow the sun's rays to be harvested. Power generation will become increasingly significant with solar energy as solar panel technology advances, reducing reliance on fossil fuels. As a result, large carbon and GHG reductions are possible.

When it comes to managing the power consumption of a home, another option is a building automation system, which is an integrated piece of technology. This technique allows for energy monitoring [8]. It enables building occupants to optimise energy use and regulate electrical equipment operations. As a result, the incorporation of a building automation system in a building is thought to potentially reduce the use of electricity.[7], [8] Water consumption can be lowered by utilizing rainwater harvesting. Rainwater harvesting reduces the dependency on the fresh water supply by supplying enough water for daily water usage. With the increased demand for water caused by a growing population, rainwater harvesting might help save water for essential uses [13], [16].

The benefits of retrofit existing buildings comes in many ways. Retrofit existing buildings can minimize or avoid any associated wastes. It is also cost-effective method for greening existing buildings, since it reduces the energy consumption, operating costs, and lifetime costs, hence, retrofitting buildings is one of the ways to reach sustainability goals.[19]

3.2 Analyzed data of C16 FKMP Building for Retrofit Case Study

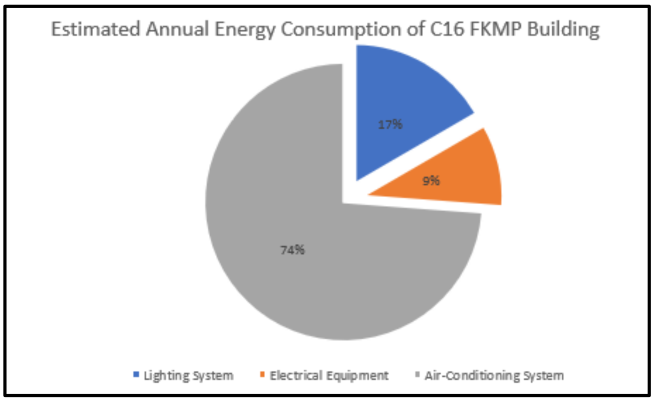
Based on the data that has been collected and summarized, it can be said that the highest energy consumption in C16 FKMP building would be air-conditioning system, then it is followed by lighting system and lastly, the electrical equipment such as computer, laptops, printers, and phone chargers. The average utility bills every month for the C16 Building would be RM 5, 737.68. Table 2 shows the estimated total energy consumption based on the site visit and walk-through inspection.

Table 2 Estimated Total Energy Consumption

Type of Consumption	Power Consumed per year (kWh/Year)	Annual Utility Rate (RM)
Lighting System	23, 629.64	11, 537.65
Air-conditioning System	104, 832.00	51, 248.05
Electrical Appliances	13, 540.8	6, 606.55
	142, 022.44	68, 852.25

To give clear and better understanding, Figure 2 shows the total estimated energy consumption of C16 FKMP building on a pie chart. The highest energy consumption is the air-conditioning under the assumption that the whole building is in its full capacity.

Figure 1 Estimated Annual Energy Consumption of C16 FKMP Building



3.3 Building Energy Index (BEI) Measurement

Building Energy Index is the ratio of the total amount of energy consumed by a building in year over the total gross area of the building. Based on the data collected, the estimated annual total energy consumption of C16 FKMP building is 65.39 kWh/year/m^2. This shows that the building is operating efficiently as per Energy Commission standards which is 135 kWh/year/m^2.

3.4 Proposed Energy Conservation Measures with Potential Savings for Retrofit Case Study

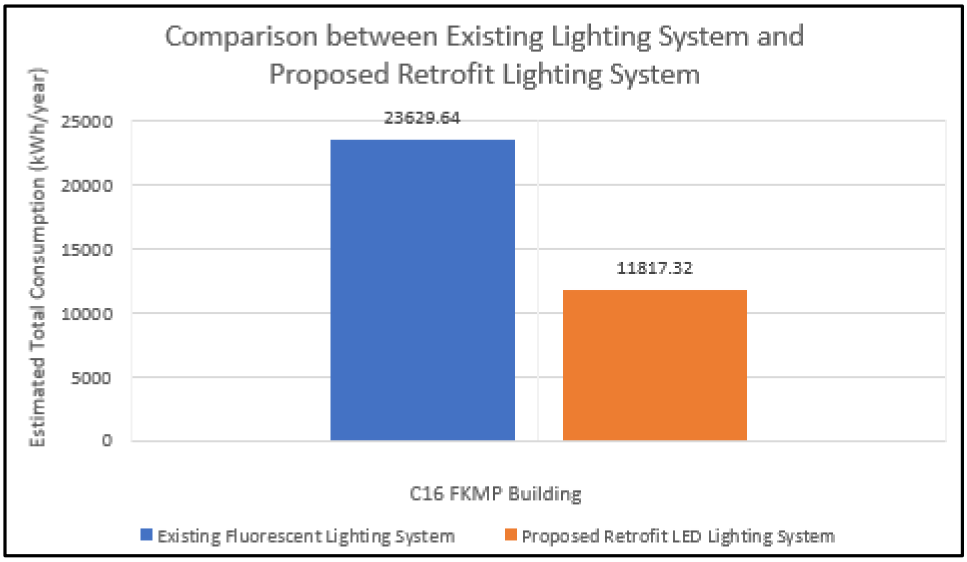
Energy Conservation Measures (ECM) are considered the upgrades, retrofits, repairs and replacement that can be implemented in a workplace to become more energy efficient. In this study, there three ECMs were proposed. The first ECM would be low-cost ECM. Low-cost ECM consists of program that educate people on how to save energy. This program would guarantee that everyone understands the importance of energy conservation. The second ECM would be medium-cost measures which involves retrofitting the existing lighting system with new LED lamp. Table 3 shows the estimation of economic analysis summary after retrofitting new lighting system.

Table 3 Economic analysis summary after retrofitting

Item	Value
Existing lighting consumption	23, 629.64 kWh/year
Estimated energy consumption after retrofit LED 18W	11, 381.76 kWh/year
Estimated energy consumption after retrofit LED 12W	299.52kWh/year
Estimated energy consumption after retrofit LED 9W	131.04 kWh/year
Estimated energy saving per year	11, 812.32 kWh/year
Estimated utility cost saved per year	RM 5, 761.42/year
Payback period	1.03 years

Figure 2 shows the comparison of energy consumption of the existing lighting system and the retrofitted LED lamps in C16 FKMP building.

Figure 2 Comparison between the existing lighting system and proposed retrofit lighting system



For high-cost measures, we would theoretically retrofit Solar PV system on the building and the premises surrounding C16 FKMP building. Based on the size of the roof, the solar panel can only supply electricity to the lighting system and electrical equipment only. Based on the estimated calculation on the consumption of lighting system and electrical equipment, total energy consumed annually would be 37, 170 kWh/year which translates in average of RM 1, 501.10 monthly in utility bills.

Table 4 Estimated Annual Energy Consumption of Lighting System and Electrical Equipment

Estimated Annual Energy Consumption	
Types of Consumption	**Consumption (kWh/year)**
Lighting System	23, 629.64 kWh/year
Electrical Equipment	13, 540.8 kWh/year
TOTAL	37, 170.44 kWh/year

After calculating the monthly average consumption, we calculate the daily average energy use, which is around 155 kWh. In order to compute the theoretical number of solar modules necessary, the average sunlight availability in Malaysia must be nine hours. Theoretically, 43 modules were needed to retrofit the C16 FKMP building in order to supply 155 kWh of electricity each day.

Retrofitting the Solar PV system will cost a total of RM 107, 087.50. The breakdown cost of retrofitting a solar PV system, to provide 155 kWh of power, is totaled at RM 96,750, or a total of 43 modules multiplied by the cost of one module, which is RM 2, 250. A 20-kW grid connect inverter costs roughly RM 5,500 to install, and wiring expenses will be charged at 5% of the entire cost of the modules, which comes out to RM 4,837.50. The formula of the estimated payback period of the retrofit cost will be shown below:

$$Payback\ Period = \frac{Retrofit\ cost}{average\ estimated\ utility\ bills} \qquad Eq. 8$$

The retrofit costs RM 107, 870.50 and divide with the average utility bills which is RM 1, 501.10. The total payback period would be 71.3 months which translates to 5 years and 9 months to recover from the initial investment.

In order to calculate bill savings after retrofitting, we multiplied the expected power savings by the average lifespan of a PV module, which is around 20 years. The total savings throughout the life of the Solar PV system will be RM 360, 264.00. The profit gain from retrofitting may be determined by taking the projected total savings after retrofitting and subtracting the cost of the retrofit solar system. During its 20-year lifespan, the C16 FKMP building may potentially save RM 253,176.50.

4. Conclusion

The project emphasizes on building energy management by retrofitting existing buildings with green energy. This study has three primary aims. This study's initial purpose was to investigate and assess the current green technology by retrofitting existing buildings with green technology. This was accomplished by doing a thorough literature analysis of prior research. The identified green technologies were solar energy, window shading, building automation systems, and rainwater collection for existing building retrofits. It is fully covered beginning in section 4.2. In addition, all findings from earlier investigations were provided. The findings of this study may be useful for industry players, building owners to invest and explore the opportunity to invest in retrofitting green technology on existing buildings in line with energy efficiency and sustainability trends.

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